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Thème : Calcul distribué et applications à très haute performance
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Abstract: Grid monitoring is an active research area, targeting both grid resources monitoring and application monitoring. Most monitoring systems aim at providing general information. However, distributed applications can benefit from a monitoring and visualization tool specifically tuned to their specific needs. This paper discusses the case of BlobSeer, a large-scale distributed storage system.

The work relies on the MonALISA framework to collect the general and specific monitoring data. In order to meet BlobSeer requirements, the visualization tool has to deal with its large-scale design, while still being able to deliver a detailed and meaningful image of the data stored.

Key-words: Distributed system, storage management, large-scale system, monitoring, visualization.

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Comment utiliser MonALISA pour surveiller la plate-forme de gestion de données réparties BlobSeer

Résumé : La surveillance des grilles est un domaine actif de la recherche, visant à la fois la surveillance des ressources et la surveillance des applications sur les grilles. La cible de la plupart des systèmes de surveillance est de produire des informations génériques. Toutefois, les applications réparties peuvent bénéficier d'un outil de surveillance et visualisation adapté à leurs besoins particuliers. Cet article étudie BlobSeer, un système de stockage réparti à large échelle.

Ce travail repose sur le système MonALISA pour collecter les données génériques et spécifiques. Afin de répondre aux défis de BlobSeer, l'outil de visualisation doit être capable de passer à l'échelle, tout en étant en mésure de fournir une image détaillée et significative des données stockées.

Mots-clés : Systèmes repartis, gestion des données, système à large échelle, surveillance, visualisation.

1 Introduction

Data-intensive scientific applications need to manage huge amounts of data and to handle read and write accesses to them. In order to address this challenge, several systems that deal with the management of large datasets have been designed. The distributed data storage systems need to cope with data striping across many storage providers and with the overhead of keeping track of the placement of the stored information. BlobSeer [5] is a system that deals with the storage of large, unstructured data and manages fine-grained read and write accesses to them under heavy concurrency.

Monitoring systems are designed to assist the users in overcoming the challenges raised by the behavior of their distributed systems. Their goal is to provide the users with the feedback necessary for identifying the state of their application and of the infrastructure where the application is running on, at a particular moment in time. Existing grid monitoring applications are mainly based on tools for monitoring the physical nodes and they mostly focus on the mechanisms of gathering and storing monitored data in a scalable and non-intrusive manner [11].

The various types of grid applications have different monitoring needs, ranging from knowing the state of the physical nodes where the application runs on, to the individual states of the jobs and the progress of file transfer operations. Even though many grid monitoring applications have been developed to address general needs [9] [2], there is little work done when it comes to defining specific parameters for data storage applications. For instance, the distribution of the stored files over the nodes is a crucial parameter in this case. MonALISA [4] is the system selected in this paper to fulfill the monitoring tasks, as it is designed for large-scale environments and it enables the user to collect application-specific information. It also allows the user to define his own data aggregation rules and to visualize the monitored information using predefined or external graphical libraries.

This paper addresses the needs of a storage system from the point of view of a monitoring system. It discusses the useful data that should be collected by the monitoring tools in order to present the user with a a detailed and meaningful image of the storage system and of the data that it is storing. A key point is to identify the graphical representations that best suit this purpose. The paper also examines the monitoring challenges raised by a large-scale storage system, such as the large number of nodes, the fine-grained striping of the data over the storage nodes and the heavy concurrent access to data, as it is the case with BlobSeer. The MonALISA system is a monitoring framework able to meet these challenges and a visualization tool tuned for BlobSeer can rely on it for gathering the required monitoring information.

The remainder of the paper consists of the following sections. Section 2 provides a brief description of BlobSeer and Section 3 presents MonALISA, the monitoring system on which our visualization tool relies. Section 4 presents the specific parameters that can be useful in observing a storage system and reports on the obtained experimental results. It identifies the visual representations suited for BlobSeer that offer the user a detailed view of the system state and can scale with the huge amount of stored data. Section 5 draws conclusions and directions for future development.

2 BlobSeer – a grid data-sharing service

2.1 Design

BlobSeer is a data-sharing system that manages the storage of large and unstructured data blocks called *binary large objects*, referred to as BLOBs further in this paper. The blobs are striped into small chunks that have the same size, called *pages*.

BlobSeer addresses the problem of efficiently storing massive BLOBs in large-scale distributed environments. It provides an efficient fine-grained access to the pages belonging to each BLOB, as well as the possibility to modify them, in a distributed, multi-user environment.

One of the entities involved in the architecture of BlobSeer is the *client*, which initiates all BLOB operations: CREATE, READ, WRITE and APPEND. There can be many concurrent clients accessing the same BLOB or different BLOBs in the same time. The support for concurrent operations is enhanced by storing the pages belonging to the same BLOB on multiple *storage providers*.

The system has to keep track of the pages distribution across providers. Therefore, it associates some metadata to each BLOB. For each BLOB, the metadata is organized as a *distributed segment tree* [12], where each node corresponds to a version and to a page range within that version. Each leaf covers just one page, recording the information about the data provider where the page is physically stored. The metadata trees are stored on the *metadata providers*, which are processes organized as a Distributed Hash Table.

BlobSeer provides versioning support, so as to prevent pages from being overwritten and to be able to handle highly concurrent WRITE and APPEND operations. For each of them, only a patch composed of the range of written pages is added to the system, and a new metadata tree is created. The new metadata tree corresponds to a new version and points to the newly added pages and to the pages from the previous versions that were not overlapped by the added page range.

The system comprises two more entities: the *version manager* that deals with the serialization of the concurrent WRITE/APPEND requests and with the assignment of version numbers for each new WRITE/APPEND operation; the *provider manager*, the one that keeps track of all the storage providers in the system.

As far as this paper is concerned, an APPEND operation is only a special case of WRITE. Therefore, we disregard this aspect in the rest of the paper. Everything stated about WRITEs is also true for APPENDs, unless explicitly specified.

A typical setting of the BlobSeer system involves the deployment of a few hundreds of provider nodes, each of them storing data in the order of GB, and even tens of GB in the case of the use of the disk storage for each node. This implies that sizes within the order of TB can be easily reached for the BLOBs stored in the system. Furthermore, the typical size for a page within a blob can be smaller that 1 MB, whence the need to deal with hundreds of thousands of pages belonging to just one BLOB.

2.2 Specific monitoring issues

A monitoring tool designed to provide a visual representation of the BlobSeer system has to tackle several challenges. Firstly, it has to be able to monitor the physical resources for each storage provider, in order to detect overloaded providers. Secondly, it has to provide, in a comprehensible manner, not only a visual representation of the BLOB as a whole, but also of the pages that the BLOB is striped into and of the way the pages are stored on the providers.

An important feature of BlobSeer is the versioning support that enables the creation of a new BLOB version each time a WRITE operation is performed. Thus, the visualization tool has to keep track of the different versions belonging to a BLOB and to take them into account when providing a graphical representation of the BLOBs.

Another challenge for a visualization tool designed to run on top of a large-scale system is to deal with a large number of storage provider nodes and therefore with a huge number of BLOB pages, versions and with huge BLOB sizes. To address this problem, the system has to switch between an exhaustive graphical representation of all the entities in the system and a more compact, partial representation. The latter has to be capable of displaying the trends in the evolution of the system or just the entities that are the most representative for it.

3 MonALISA

BlobSeer is a storage system that deals with massive data, which are striped into a huge number of pages scattered across numerous storage providers. A monitoring tool tuned for presenting the state of a system like BlobSeer has to cope with two major challenges. On one side, it has to accommodate the immense number of pages that the system comprises once it stores several BLOBs. On the other side, the monitoring system has to be able to deal with a huge amount of monitoring information generated when an application accesses the nodes that make up the storage service. It is the case when multiple clients simultaneously access various parts of the stored BLOBs, as they generate a piece of monitoring information for each page accessed on each provider. MonALISA is suitable for this task, as it is a system designed to run in grid environments and it proved to be a scalable and reliable system.

3.1 Architecture

The MonALISA (*Monitoring Agents in a Large Integrated Services Architecture*) [10] system is a JINI-based [8], scalable framework of distributed services, which provides the necessary tools for collecting and processing monitoring information.

Its architecture is based on four layers of services, as presented in Figure 1. It complies with the Grid Monitoring Architecture (GMA) [7] proposed by the Global Grid Forum (GGF) [1], which includes three components: consumers, producers and a directory service.

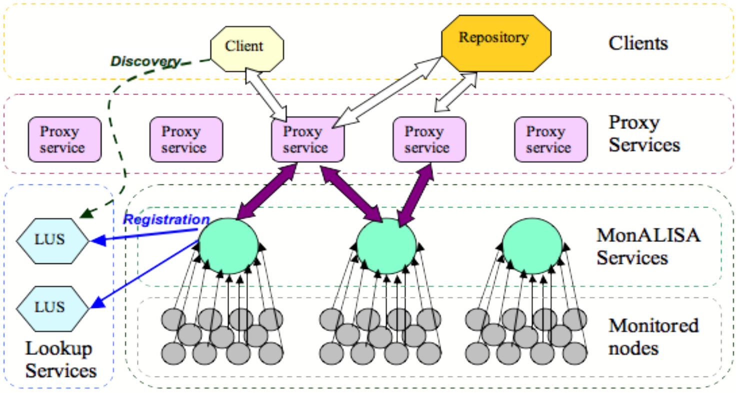


Figure 1: The MonALISA architecture

The first layer corresponds to a network of **Lookup Discovery Services** that provide discovery and notification mechanisms for all the other services.

The second layer is composed of **MonALISA services**, the components that perform the data collection tasks. Each MonALISA service is part of a group and registers itself with a set of Lookup Services, together with several describing attributes.

The interaction between clients and services is made available through transparent **Proxy services**, which represent the third layer in the MonALISA architecture. Every MonALISA service discovers the Proxy Services by using the discovery mechanism implemented into the Lookup Services layer, and permanently keeps a TCP connection with each of them.

The top-level layer is represented by the **MonALISA clients**, which offer an intuitive graphical interface of the states of the monitored systems. It allows users to subscribe to and to visualize global parameters gathered from multiple MonALISA services. It also provides detailed tracking of parameters for any individual MonALISA service or component in the entire system. The **MonALISA repository** is a "pseudo-client" for the MonALISA services, developed as a Web server. It is able to store the monitoring data and to present historical and real-time values, statistics and graphical charts for a specific group of MonALISA services. Each type of MonALISA client has to connect to the layer of Lookup services in order to request access to data gathered by one or more specified groups of MonALISA services. It is then transparently connected to the nearest and less loaded proxy service, which will forward the data that the client has subscribed to, from all the MonALISA services.

3.2 Customization

The MonALISA system is a well-suited choice for monitoring a distributed storage system, thanks to several features that it provides. First of all, it can monitor both a set of predefined parameters and various user-defined parameters. This is due to an application instrumentation library, called ApMon, that enables any application to send monitoring information to one or more MonALISA services.

```
#include "ApMon.h"

ApMon *apm = new ApMon(ConfigFile);
        ...
apm -> sendParameter("MyParameterGroup", "NodeName",
                "MyParameter", XDR_REAL64, (char *)&value);
        ...
```

Figure 2: Instrumenting a code with the *ApMon* Library.

BlobSeer is instrumented using the ApMon library, requiring each provider to report to the monitoring system each time a page is written or read, by sending a parameter and its value to a predefined MonALISA service, as described in Figure 2.

The version manager is monitored in the same way. An ApMon-based daemon parses its log file each time it is updated, in order to report the written page ranges and their associated versions. The state of the physical resources on each node is monitored through an ApMon thread that periodically sends the data to the monitoring service.

The MonALISA system also enables the user to create new data from the collected values, through the use of filters. In this way, new or aggregated values can be dynamically created within independent threads while the MonALISA service or repository receives the monitoring information. Since by default the repository can accommodate only time series in its database, all the specific data monitored from BlobSeer go through a filter that stores them into the corresponding database tables.

Another element is essential for defining a visualization tool tuned for a particular storage system. It is the possibility of having customized graphical charts, appropriate to the collected parameters. The MonALISA repository supports the integration of external graphical libraries, thus opening the way to the generation of any type of chart for any type of user-defined parameters.

4 Monitoring BlobSeer using the MonALISA framework

This paper proposes a visualization tool designed to provide a comprehensive image of the BlobSeer system, able to extract useful information from the huge number of entities and monitoring parameters that account for a typical BlobSeer instance. It relies on the MonALISA monitoring system to address the challenges raised by the data-gathering tasks. Our contribution lies in the fact that the proposed visualization tool can handle the huge bursts of monitoring data generated when countless pages are simultaneously read from or written into the stored BLOBs. It is designed to adapt to the various sizes of the datasets and to provide appropriate graphical representations for the different aspects of the system.

4.1 Experimental plan

The visualization tool we developed has been evaluated on the Grid'5000 [3] [6] testbed, a large-scale experimental grid platform, with reconfiguration and control capabilities. The Grid'5000 platform covers 9 sites geographically distributed in France, built as a network of dedicated clusters.

For the experiments, we used 127 nodes belonging to a single cluster in Rennes. The nodes are equipped with x86_64 CPUs and at least 4 GB of RAM. They are interconnected through a Gigabit Ethernet network.

We deployed each BlobSeer entity on a dedicated node, as follows: two nodes were used for the version manager and the provider manager, 10 nodes for the metadata providers, 100 nodes for the storage providers and 10 nodes acted as BlobSeer clients, writing data to the BlobSeer system. Four nodes hosted MonALISA services, which were responsible for gathering the monitoring data for all the provider nodes. A MonALISA repository was deployed outside Grid'5000, as there are no direct connections between the MonALISA services and the repository. All the monitoring traffic goes from the monitored nodes to the MonALISA services. Each MonALISA service keeps permanent connections with the proxy services and it forwards the monitoring data that the repository has subscribed to through these connections.

The experiment assesses the conformity of the obtained charts with the real state of the system and the ability to produce scalable results regardless of the size of the stored data, of the number of BLOB pages, or of the number of accesses.

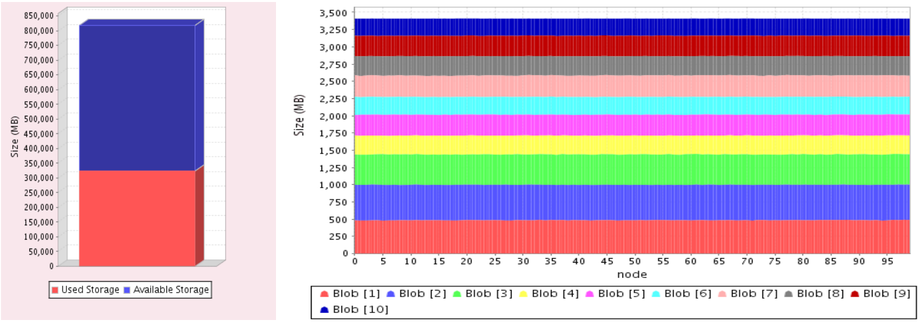
In this experiment, we used 10 BLOBs, each of them having the page size of 1 MB and a total size larger than 20 GB. We started the 10 clients, each of them being required to create a BLOB and to write 10 data blocks of 2 GB each on the created BLOBs. Each data block overlaps the previous one by 10%. Next, we started the clients in parallel and each of them performed a number of WRITE operations on a randomly selected BLOB. The blocks were written on the BLOB at random offsets and they consisted of a random number of pages, ranging between 512 MB and 2 GB in size.

This experiment lasted for a dozen of minutes. All the figures below are real snapshots of the final state of this experiment.

4.2 General resource monitoring

Every grid monitoring tool is able to collect resource information. A monitoring system tuned for BlobSeer has to tackle this task as well, so as to be able to characterize the overall usage of the resources involved in the system. The physical resources that need to be monitored include regular monitoring parameters like computing cycles, CPU usage, network traffic, disk usage, storage space or memory.

The most important resources for a storage system are the storage space and the memory. A visualization tool has to provide information about both the state of the entire system and the distribution of the storage capabilities across the providers which this system consists of. For each provider, the information that has to be collected is represented by the used/available memory and used/available storage space.



(a) Global view of the used and available storage space

(b) BLOBs distribution across providers

Figure 3: Storage space monitoring

The visualization system has to be able to adapt the granularity of the system views to the needs of the client, thus proposing two different approaches that deal with the representation of the storage space or the memory. The graphical representations that follow only refer to the storage space, as the ones related to the memory are similar.

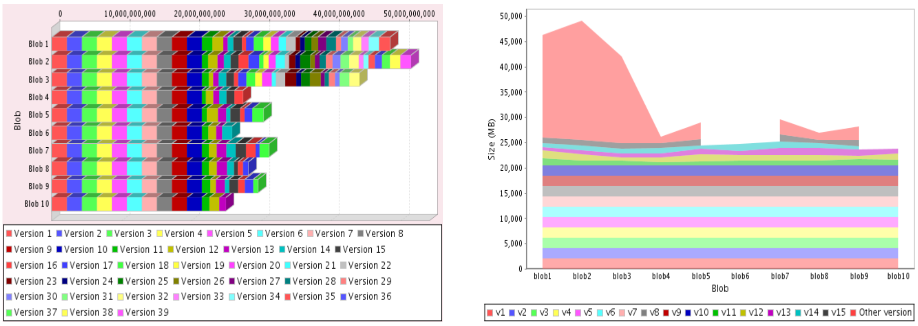
The global view It depicts the current values of the available and used storage space for the entire system. These values represent the sum of all the most recent free and used space amounts reported by the storage providers, merged in an intuitive view (Figure 3(a)).

This is a real-time measure of the system load. In the future BlobSeer releases, it will be a crucial information to modify the number of running storage providers dynamically, as the available storage space decreases. In our experiment, the chart in Figure 3(a) reveals the fact that the system was not overloaded, thus indicating a stable and safe state of the system.

The detailed view If the global view of the storage space reflects the system load, the detailed view informs the user of the occupied and available space at each storage provider.

Each provider reports the value of the used storage space each time new data are written to it, enabling the monitoring tool to keep track of the states of all the entities that make up the storage system. The visual representations of these collected data can vary from displaying the values of the used and free storage space across the providers, to the list of the most loaded providers in the system.

Note that both these approaches scale well with the number of providers. In the first case, the used storage space can be displayed as a set of averaged values for the adjoining providers, instead of individual values for each of them. In the case of the list of overloaded providers, the number of displayed providers can be selected by the user, so as to highlight the providers that require the system to trigger an action meant to decrease their load.



(a) Comparison between BLOB versions and sizes

(b) BLOB versions and sizes for a large number of BLOBs

Figure 4: BLOB versions and sizes

4.3 Global BlobSeer monitoring

In order to have an overview of all the data currently stored in the BlobSeer system, the BLOBs and their configuration can be presented from several different points of view.

The distribution of the BLOBs across providers The visualization system has to offer a complete image of the storage system and of the way the data is stored. It has to be able to handle TB-sized BLOBs scattered on hundreds of storage providers.

This general image exposes the total sizes of the stored BLOBs, as well as the the way they are stored on the providers, providing the user with a comprehensive understanding of how the system manages the stored data (Figure 3(b)). The chart draws attention to the variations of the loads across providers and it can scale with respect to the number of providers or to the BLOB size. In case the number of BLOBs is too large and the chart cannot accommodate it, or the load variations are experienced only between a few BLOBs, the user can have a closer look to a specified range of BLOBs, by selecting an interval of BLOBs to be shown and group all the others in a single representation of their total size.

The chart in Figure 3(b) reveals the balanced storage-space usage among the providers deployed in our experiment. This behavior is a consequence of the fact that they are allocated in a round-robin manner and that our experimental environment, Grid'5000, provides a low latency network between all the used nodes.

However, the displayed information is a deciding factor in dynamically adapting the provider allocation policy, when the monitoring system reveals high variations between the loads reported by the providers. On the other hand, the chart provides a means to visually compare the sizes of the different BLOBs in the system, on the same chart that exposes the total size of the stored data. In this case, due to the well-balanced providers, the total size can be easily interpreted as being the number of providers, 100, multiplied by the size stored by each provider, which is about 3 GB.

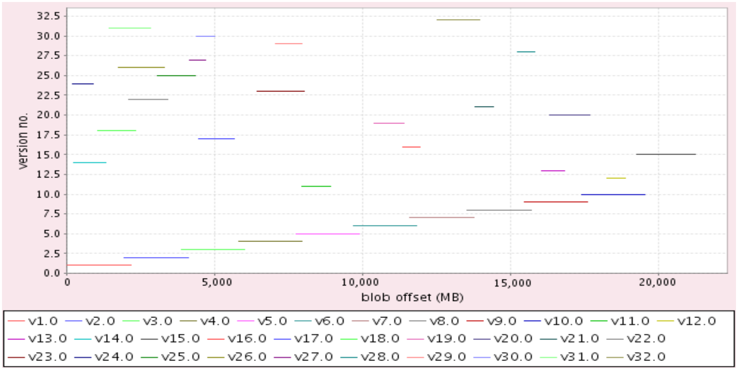


Figure 5: The structure of a BLOB

The structure of all the stored BLOBs They are depicted in Figure 4(a), where the user can compare the sizes of the versions within a BLOB and the sizes of the ones corresponding to different BLOBs. The size of the versions is given in the total size of the pages that compose the versions. For the first version the size is the whole size of the written data. For the next versions, the size is just the size of the pages added or modified when the version was created, so the user can also compare the storage space occupied by various BLOBs.

This representation of the whole system can only cope with a limited number of BLOBs and BLOB versions. When the number of BLOBs grows over a fixed value, the user can no longer see the details associated with each BLOB. In this case, the chart automatically switches to a more compact representation that does not expose all the details, but instead it allows the user to detect the trends of the BLOBs' structure across the system, as presented in Figure 4(b). If some of the versions have particularly small sizes that cannot be visually distinguished, their sizes are summed up and represented as another series that contains them all (the *Other versions* series in Figure 4(b)).

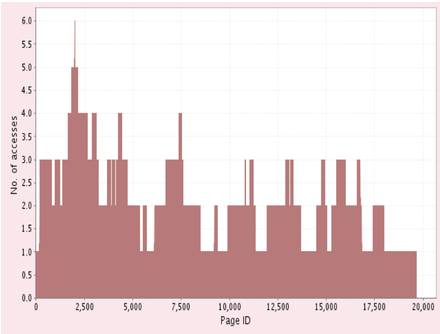
Figure 4(a) confirms the creation of the first equally-sized 10 versions for each BLOB, as we stated in the description of the experiment. This chart is updated in a real-time manner, after each WRITE operation ends. It is a useful tool that shows the dynamic growth of the BLOBs and an intuitive image of their sizes and, furthermore, of the distribution of the size among versions.

This chart can be correlated with one that emphasizes the number of write operations performed on each BLOB, which is equivalent with the number of versions. It exposes the BLOBs that have a high rate of change or growth, as opposed to the BLOBs that contain data that is seldom modified.

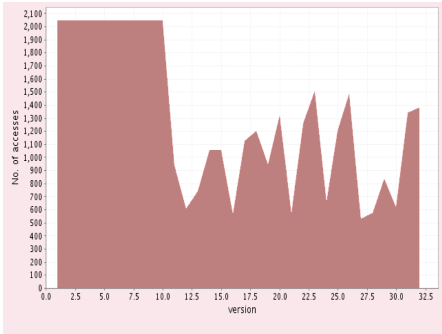
4.4 Individual BLOB monitoring

4.4.1 The structure of a BLOB

The structure of a BLOB, i.e., the page ranges occupied by each version, can be a convenient information for the client. Figure 5 displays all the versions for a specified BLOB as lines covering a range of pages. This chart can accommodate a large number of versions, thus being suitable for describing BLOBs that are



(a) Number of write accesses on the logical address pages for a BLOB



(b) Version access patterns

Figure 6: BLOB accesses visualization

subject to many WRITE operations. It scales to any number of BLOB pages stored in the system, as the versions are depicted as ranges and, consequently, the chart scales well even for the BLOBs that are composed of a huge number of pages.

Figure 5 corresponds to the third BLOB, one of the largest BLOBs in our experiment (as shown in Figure 4). The figure emphasizes the placement of the versions within a BLOB. For instance, the structure of the BLOB after the first series of 10 WRITE operations reveals the first 10 versions, each of them having a size of 2 GB and overlapping the previous one by 10%.

The information provided by this chart allows the user to verify that the WRITE operations he initiated generated new versions in the requested positions within the BLOB. The chart is also a visual depiction of the ranges of pages that are overlapped by newer versions and that are no longer needed for the accesses to recent versions.

4.4.2 Read/Write accesses monitoring

The number of times a provider, BLOB, version, or page were accessed is a significant parameter that the monitoring system has to be aware of. It is the criterion used to find access patterns for the data stored and, together with the information about the memory and the CPU load, the number of accesses can be a valuable input for a provider allocation algorithm.

The visualization of the read/write accesses It is represented by a chart that illustrates the access patterns for a BLOB, as displayed in Figure 6(a). The chart is drawn either starting from the number of read accesses for each page that the BLOB version consists of, or starting from the number of write operations performed on the BLOB for each page. Since each WRITE or READ operation consists in accessing a range of consecutive pages, it is expected that some ranges of pages will have the same number of accesses, thus revealing an access pattern through this visual representation. The chart can aggregate data comprising a huge number of BLOB pages, enabling the user to identify the regions of the BLOB composed of pages with the same number of accesses in a scalable way.

The distribution of the read/write accesses across the BLOB versions BlobSeer provides a versioning system that creates a new version for a BLOB every time a write operation is performed on that BLOB. The versions can be weighted by counting the number of read accesses or of physical memory pages for each of them, as shown in Figure 6(b). This chart can accommodate a huge number of versions associated with a massive BLOB, by displaying only a set of averaged values between the consecutive versions, when their total number is too large to be shown on a single chart. It depicts the tendencies of the READ operations over the versions or the various sizes of the WRITE operations, as the number of write accesses for a specified version is equivalent with the number of pages written.

5 Conclusion

This paper addressed the challenges that have to be tackled by a visualization tool that aims to provide an extensive and intuitive image of a large-scale storage system that deals with TB-sized data, such as BlobSeer. The goals of the paper were to select a set of specific monitoring data that can be collected from BlobSeer and to map the stored data onto a graphical representation that can scale with the huge number of BLOBs and pages stored. It has to be both an easily understandable and an in-depth depiction of the state and the structure of the system. This paper presented an experiment that shows the advantages of having a monitoring system tuned for BlobSeer. Even though it did not deal with the huge amounts of data that are typical for BlobSeer, we argue that it demonstrates the scalability of the monitoring approach.

The massive number of monitoring parameters generated for each page written imposed the use of multiple MonALISA services that share the load of collecting the data from the providers, whereas the initial experimental plan required just the use of a single MonALISA service. We decided to use an online processing of the monitoring data, so as to provide an almost real-time image of the system, by correlating the high-level data operations with the numerous low-level page storage ones.

The gathered data can be the starting point towards an online interactive or self-steering mechanism for BlobSeer. The collected data facilitate the design of a provider allocation mechanism that takes into account the various attributes of the storage providers, such as their load, the number of accesses performed on them or the number of pages or BLOBs they store. The number of deployed providers can also be automatically managed, due to the monitoring information that draws attention to the percentage of overloaded providers, the global load of the system or to the number of providers under heavy concurrent accesses. Another BlobSeer feature that can benefit from the monitoring information is the replication strategy, as the replication factor of one BLOB or page can be modified according to the previously collected data that emphasize the number of read accesses or the load of the system.

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